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3. Full name, address and postcode of the or of each applicant *(underline all surnames)* — Robert Michael Lipman, 2-B Sorotzkin Street, Jerusalem 94423, Israel

   Patents ADP number *(if you know it)* — 8399339001

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4. Title of the invention — Control Apparatus

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DUPLICATE

Control Apparatus

The present invention relates to control apparatus and in particular to control apparatus for the remote control of data or equipment.

There are many situations in which wireless remote control of equipment or data is particularly desirable. In many of these situations it would be particularly advantageous for control to be dependent on the two or three dimensional position of a free moving control device relative to a control panel or the like.

Three dimensional remote control may be particularly advantageous, for example, for improving the quality of life of severely disabled people. Such control may be used by people with severe mobility impairment, for operating special needs vehicles, household equipment computers or the like. Three dimensional remote control would allow the minimum effort with no pressure being required to operate switches or the like. Conveniently, the control device could be configured to the needs of the disabled person allowing him to wear the device in a convenient position for mobility.

Three dimensional remote control also has applications in three dimensional design. It would be particularly beneficial, for example, for a designer to be able to create a 'virtual' 3D design by tracing a three dimensional image in mid-air above a control panel in the form of a sensor plate. A computer design system integrating a wireless, freely held control device in the form of a stylus or the like would allow a more seamless, intuitive, and artistic effort.

It is an object of the invention to provide an improved control apparatus for the remote control of data or equipment.

According to one aspect of the invention there is provided control apparatus for the remote control of data or equipment, comprising: a screen; input means; sensing means for sensing data related to a position of the input means relative to the screen; control means for determining the position of the input means relative to said screen from the data; wherein, the input means includes a source of electromagnetic radiation for directing onto the screen; the

sensing means includes detection means for detecting electromagnetic radiation directed onto, and scattered by the screen; the detection means being configured to produce a detector output dependent on the scattered electro-magnetic radiation detected; and the control means being configured to analyse the detector output to determine the position of the source relative to the screen.

Preferably the source is configured to produce a conical beam of infrared radiation for directing onto the screen to form an elliptical area of incident radiation.

The source may be configured to produce a laser beam for directing onto the screen.

Preferably the control means is configured to analyse the detector output, to measure the length of either a major axis or a minor axis of the incident elliptical area, and to calculate the distance between the source and the screen from said measured length.

Preferably the control means is configured to analyse the detector output to measure angle related parameters of electro-magnetic radiation directed by the source onto the screen, and to determine the angle of the source relative to screen from the measured parameters.

Preferably the area related parameters include the length of either a major axis or a minor axis of the incident elliptical area.

Preferably the source is configured to split the laser beam into a plurality of components for directing onto the screen to form a plurality of corresponding incident points.

Preferably the control means is configured to analyse the detector output to measure the distances between the incident points.

The control means may be configured to determine the distance of the source from the screen from at least one of the measured distances.

The control means may be configured to determine the angle of the source relative to the screen from the measured distances.

Preferably the detection means comprises a plurality of detectors arranged along at least one edge of the screen; each detector being configured to produce an analogue output dependent on the quantity of scattered light detected by it.

Preferably the detection means is configured to produce detector output in the form of a serial signal, and the detection means further comprises a converter configured to convert the analogue outputs into the serial signal.

According to another aspect of the invention there is provided a method of determining a position of an input means relative to a screen comprising: directing electromagnetic radiation onto the screen from the input device; detecting electromagnetic radiation directed onto, and scattered by the screen; producing a detector output dependent on scattered electro-magnetic radiation detected; and analysing the detector output to determine the position of the input device relative to the screen.

The present invention will now be described, by way of example only, with reference to the accompanying drawings in which:

Figure 1 shows illustratively a device incorporating the invention;

Figure 2 shows illustratively a screen in use with a pointer according to one embodiment of the invention;

Figure 3 shows illustratively a plan view of the screen of figure 2

Figure 4 shows illustratively a pointer according to another embodiment of the invention in operation;

Figure 5 shows illustratively the screen in use with the pointer of figure 4; and

Figure 6 shows illustratively a plan view of the screen of figure 5.

Referring to Figure 1, an electronic device is shown generally at 10. The device 10 may be,

for example, a hand-held or "palm-top" computer, a personal digital assistant (PDA), a PC screen, or a mobile communication device such as a mobile telephone. Alternatively the device may be an electronic control panel for controlling electronic equipment such as surgical apparatus, an electric vehicle or the like.

The device 10 has a screen 12, for displaying data, or control options for controlling electronic equipment. In operation, the data displayed or the electronic equipment is controlled by means of an input device. In the preferred embodiment the input device takes the form of a pointer 16, which may be of any suitable form, for example a pen-shaped "stylus", a glove, a visor, a gun, or any suitable remote unit. The pointer 16 allows the user to operate the device 10 by selecting various options displayed on the screen 12.

The screen 12 is made of a relatively, transparent material with small but significant scattering properties, for example, commercial grade Perspex or the like. Hence, in operation, when the pointer 16 emits a beam of light onto a region of the screen 12 most of the light incident on the screen 12 is transmitted through the screen 12 and some of the light is scattered towards the edges of the screen 12. The quantity of transmitted light passing through the screen 12 decreases exponentially with the thickness of the screen 12. The quantity of scattered light arriving at the edges of the screen decreases exponentially with distance from the region of incident light.

As shown in figures 2 and 5, the screen 12 includes a plurality of horizontal detectors 20, and vertical detectors 22, arranged along the edges of the screen 12 in the x and y directions respectively. The detectors 20, 22 are configured to detect the scattered light and typically have a relatively narrow field of view, for example ~8°. They may be of any form suitable for detecting electromagnetic radiation of the type emitted by the pointer, for example, conventional photo detectors.

The pointer 16 is provided with a source of electromagnetic radiation, for example an infrared emitter, a laser, an LED or other such light emitting device.

In figure 3 a pointer according one embodiment is designated 16'. The pointer 16' emits a

conical beam of light, as best illustrated in figure 3, from a circular, spherical, or other shaped tip (not shown). The light emitted is modulated in order to avoid interference from ambient light.

In operation, when the pointer 16' emits a beam of light onto a region of the screen 12, each detector 20, 22 detects a portion of the light scattered from the incident beam and produces a corresponding analogue output 24, 24' with a magnitude dependent on the quantity of scattered light detected. The analogue outputs 24, 24' are received in parallel by a converter 26, 26', which produces a corresponding serial output 28, 28'. The serial output 28, 28' is inputted to the device 10 which analyses the signal to determine pointer parameters, for example the relative X, Y and Z position and/or angle of inclination of the pointer 16.

The converter 24, 24' is of any suitable type and may be an analogue to digital converter. The serial output may be in the form of a digital serial signal or an analogue serial signal.

The horizontal detector 20, and vertical detector 22, with the highest magnitude analogue output correspond respectively to the x and y positions of the incident beam. Hence, in operation, the device 10 measures the magnitude of the analogue outputs, determines the x and y position of the incident beam from the measured values, and responds appropriately.

In operation, the accuracy of the position determined is improved by interpolation between the values of the outputs measured for multiple detectors. In each direction the value measured for the detector with the highest magnitude output is interpolated with the values measured for adjacent detectors using a polynomial function. The polynomial function is quadratic having the form:

$$V(x) = ax^2 + bx + c \qquad \text{for the x direction}$$

and

$$V(y) = a'y^2 + b'y + c' \qquad \text{for the y direction}$$

where the functions V(x) and V(y) are the values of the outputs of the detectors at position x

and position y respectively. The constants a, a', b, b' and c, c' are determined by finding the best-fit to the measured values. The interpolated best value is approximated by:

$$x = -b/2a \qquad \text{for the x position}$$

and

$$y = -b'/2a' \qquad \text{for the y position}$$

Hence, a more accurate value of x and y position are found.

The region of the screen 12 on which the light is incident will be substantially elliptical with an area dependent upon the distance of the pointer 16' from the screen. The eccentricity of the ellipse will depend on the angle at which the beam strikes the screen and hence on the angle at which the pointer is held. An eccentricity of 1, for example, is indicative of a circle of incident light and the pointer 16' held perpendicular to the surface of the screen.

The relative magnitudes of the analogue outputs 24, 24' are used to determine the lengths of the major and minor ellipse axis and hence the eccentricity the ellipse. The angle of the pointer 16' is then calculated using conventional mathematics. Similarly the length of either the major or minor ellipse axis is used to calculate the distance of the pointer from the screen in the Z direction. Where the ellipse is a circle, the length of both ellipse axis will be equal, corresponding to the diameter d of the circle as seen in figure 3.

The ratio of the constants a to a' derived from the interpolation is also a measure of the angle of the pointer 16' relative to the screen 12. Hence, in operation the constants derived from interpolation may also be used to improve the accuracy of the angle determined.

The intensity of the light incident on the screen is also dependent on the distance of the pointer 16' from the screen 12. Correspondingly, the quantity of scattered light detected by the detectors 20, 22, and hence the magnitudes of the analogue signals 24, 24' vary with the intensity of the incident light. Hence, the absolute magnitudes of the analogue signals 24, 24' may also be used, either to independently determine the distance of the pointer 16' from the

screen 12, or to refine the result of the calculation based on the ellipse measurements.

The distance of the pointer 16' from the screen 12 is also generally inversely proportional to the constants a and a' derived from the interpolation. Hence, in operation the constants derived from interpolation may also be used to improve the accuracy of the z position determined.

The angle of the pointer 16', in conjunction with the distance of the pointer 16' from the screen 12 are then used to determine the distance of the pointer-16' from the screen 12. Hence the position of the pointer 16', in the Z-dimension, is determined by the device 10.

The location and angle of the pointer 16', may also be used to determine when the user makes a selection without physical contact between the pointer 16' and the screen. A simple dipping motion, for example, could be used to represent the selection. Alternatively or additionally the area and / or intensity of the light may also be used to represent a contactless selection. Such a selection may be indicated, for example, by the area of incident light falling below a certain minimum threshold and / or the intensity rising above a certain maximum threshold.

Figure 4 shows a pointer 16'' according to another embodiment of the invention. The pointer 16'' includes a laser source 40, three beam splitters 42, 44, 46 and a window 48. The laser source may be of any suitable type, for example, a laser diode or the like.

The laser source 40 is located within the pointer 16'' and is configured to produce a laser beam 50 in an axial direction of the laser source 40. The beam splitters 42, 44, 46 are in the form of planar, semi-reflecting mirrors arranged within the pointer 16'' arranged at intervals along the operational path of the laser beam 50. Each beam splitter 42, 44, 46 is positioned at an angle $\alpha/2$ relative to the axial direction of the laser source 40. Hence, in operation each beam splitter 42, 44, 46 splits the laser beam 50 into a first component, which passes through the splitter with no change in direction, and a second component, which is deflected through an angle α.

The first, second and third beam splitters 42, 44, 46 are located progressively further from the

laser source 40. The second and third beam splitters 44, 46 are respectively rotated through 120°, and –120°, relative to the first beam splitter 42 about the axial direction of the laser source 40. Hence, in operation the laser source produces the laser beam 50, which passes through each beam splitter 42, 44, 46, in turn. Thus, the beam is split into four components comprising three deflected components 52, 54, 56 and a transmitted component 58. As seen in figure 5 and 6, in operation, the deflected components 52, 54, 56 incident on the screen 12, form the vertices of a triangle. The incident transmitted component 58 lies substantially at the centre of the triangle.

Each beam splitter 42, 44, 46, may be made of any suitable material, for example, microscope cover glass. The splitters 42, 44, 46, are each provided with a thin-film optical interference coating for controlling the relative transmittance and reflectance of each splitter 42, 44, 46 and hence the relative intensity of the deflected and transmitted components 52, 54, 56, 58. Alternatively or additionally the pointer 16'' may be provided with an absorbing filter 60 located in the operational path of the transmitted component 58 for attenuating the intensity of the transmitted component 58 relative to the deflected components 52, 54, 56.

Thus, in operation, the intensity of the transmitted component 58 is different to the intensity of the deflected components 52, 54, 56. Hence, when the components of the laser beam 50 are incident on the screen 12, the transmitted component 58 can be distinguished from the deflected components 52, 54, 56.

By way of example, when the beam splitters 42, 44, 46 are made of microscope cover glass and α is set to approximately 13°, the associated ratio of transmittance to reflectance is approximately 1:1. Hence, the intensity of the transmitted component 58 emerging from the third beam splitter 46 is approximately: 25% of the intensity of the first deflected component 52, deflected by the first beam splitter 42; 50% of the intensity of the second deflected component 54, deflected by the second beam splitter 44; and equal to the intensity of the third deflected component 56, deflected by the third beam splitter 46. The absorbing filter 60 reduces the intensity of the transmitted component 58 further so that it is less than that of the other components.

The window 48 is located at the end of the pointer 16'' in the operational path of the transmitted component 58 of the laser beam 50. The window 48 is of suitable size and configuration to allow passage of all three deflected components 52, 54, 56 and the transmitted component 58 during operation.

The use of the laser source 40 is particularly advantageous for operation of the device 10 from a distance, since laser beams have extremely narrow spreads and maintain a relatively high intensity over long distances. It will be appreciated that the precise location and arrangement of the laser source 40 and beam splitters may vary dependant on requirements. For example, where remote operation is required from a distance, the angle α may be particularly acute.

Operation to determine the three dimensional position and orientation of the pointer 16'' is similar to that described for the pointer 16' having a conical beam.

In operation, when the pointer 16'' emits the components of the laser beam 50 onto a region of the screen 12, a number of the detectors 20, 22 detect light scattered from the incident components and produce a corresponding analogue output 24, 24' with a magnitude dependent on the quantity of scattered light detected. The analogue outputs 24, 24' are received in parallel by a converter 26, 26', which produces a corresponding serial output 28, 28'. The serial output 28, 28' is inputted to the device 10 which analyses the signal to determine pointer parameters, for example the relative X, Y and Z position and/or angle of inclination of the pointer 16''.

The X position of each component is determined from the relative magnitudes of the signals 24 from the horizontal detectors 20. Similarly the Y position of each component is determined from the relative magnitudes of the signals 24' from the vertical detectors 22. As discussed the intensity of the transmitted component 58 is different to that of the other components of the laser beam 50. Hence, the X and Y positions corresponding to the incident transmitted component 58 is distinguished from the positions of the other components and the device 10 can respond appropriately, for example, by highlighting an icon at which the pointer is directed.

Referring to figure 6 the distance between the transmitted and deflected components 52, 54, 56, 58 incident on the screen 12 is determined from their relative positions and hence the distance in the Z direction can also be determined by conventional trigonometry.

As with LED light the intensity of laser light incident on the screen is also dependent on the distance of the pointer 16'' from the screen 12. Correspondingly, the quantity of scattered light detected by the detectors 20, 22, and hence the magnitudes of the analogue signals 24, 24' vary with the intensity of the incident laser light. Hence, the absolute magnitudes of the analogue signals 24, 24' may also be used, either to independently determine the distance of the pointer 16'' from the screen 12, or to refine the result of the calculation based on the trigonometrical calculations.

The relative distances between the transmitted and deflected components 52, 54, 56, 58, incident on the screen 12 is indicative of the equality of the triangle formed by the incident deflected components 52, 54, 56. For example, when the pointer 16 is held with the transmitted component 58 perpendicular to the screen 12, the triangle formed by the deflected components 52, 54, 56, is substantially equilateral. When the transmitted component 58 is not normal to the screen 12, the triangle formed is not equilateral and the distances between the components reflect this. Hence, the angle at which the pointer 16 is being held relative to the screen 12 is determined using conventional trigonometry.

The angle of the pointer 16'', in conjunction with the distance of the pointer 16'' from the screen 12 are used to determine the distance of the pointer 16'' from the screen 12. Hence the position of the pointer 16'', in the Z-dimension, is determined by the device 10.

Repetitive calculation of the pointer position, several times a second as the pointer 16'', is moved allows a pointer trajectory to be recorded. The pointer trajectory may then be used to assist in anticipating the intentions of the user or for advance control functions.

The location and angle of the pointer 16'', may also be used to determine when the user makes a selection without physical contact between the pointer 16'' and the screen. A simple dipping motion, for example, could be used to represent the selection.

It will be appreciated that although the invention has been described with reference to an embodiment in which the three dimensional position of a pointer may be determined, the invention is equally applicable for determining the position of the pointer in two dimensions only or even a single dimension.

It will further be appreciated that although the invention has been described with reference to particular applications there are numerous other ways in which the invention may be applied. A number of applications will now be described for the purposes of illustration.

The invention has particular application in the medical profession. For example, for computer-aided surgical procedures such as laparoscopy, microsurgery, and endoscopy. In this case the light source could be built into tip of a pointer in the form of a scalpel or other tool for a more natural feel for a doctor or surgeon.

In telemedicine the invention may be used for the control of cameras and medical equipment in remote medical examinations or procedures.

The invention may also be incorporated into equipment for training purposes. For example, it would be particularly beneficial in medical student training, for allowing simulated medical procedures to be carried out on computerized dummies such as CPR training mannequins or using other computer controlled simulators. A pointer in the form of a light-tipped surgical tool could be used to enhance the realism of the simulation making it more effective. Potentially such use could also reduce the requirements for cadavers in medical training.

The invention would also be of advantage in applications where there is a requirement for the human operation of equipment based in hazardous environments such as the vacuum of space or military settings. Examples of such uses include the intuitive control of unmanned equipment and the external repair and adjustment of space based vehicles and equipment. A single hardware system could therefore be programmed with separate programming preferences for each piece of equipment, minimizing weight and equipment limitations on board.

The invention also has many applications in small scale research, engineering and manufacturing including biotechnology, biology, semiconductors and nanotechnology. In situations where the operator is working with items too small to be seen by the naked eye, a system can be devised to integrate the pointer with a computerised microscope, for example, an electron-microscope or the like. The microscopic real-time image can then be used in conjunction with the pointer to control the microscope and to guide manipulate a 'workpiece'. In this application it would be particularly beneficial if the light source were a laser since this can be focussed extremely precisely.

Beneficial functionality may include, for example, simultaneous zoom control in conjunction with active functions in a single wireless pointer in the form of a stylus or other tool. The pointer being used directly "on" a microscope image for designing microchips, investigating viruses or genes.

The invention may also be incorporated into equipment for fertility treatments, such as ICSI (intracytoplasmic sperm injection). In ICSI a microscopically tipped pipette is used to select a single sperm and to inject it into an egg. Having the pipette controlled by an operator holding a pointer in the form of a computer-driven, light-tipped "pipette" and working directly on the microscope-generated image would have obvious advantages. The same principle applies to ex vivo treatment (IVF), colonoscopy, and other invasive biopsy investigations, where trauma to a patient needs to be minimised.

In all these situations the pointer is a hand held tool which does not come into direct contact with the work in progress. This allows appropriate preferences and tolerances to be set to reduce the probability and magnitude of errors caused by under-compensation, over-compensation or undesirable movements.

A further application of the invention is for the enhanced control of televisions and other entertainment equipment. A light-sensitive screen in combination with an appropriately configured pointer could be used in a way similar to current remote-control systems, but with additional enhancements. For example, adjustability of a "frame within a frame" could be provided with "click and drag" being used to adjust the size of the second frame. Similarly,

provision could be made for direct on-screen programming of a VCR, other recording device or integrated media.

A particular advantage in these applications is the provision of button-free menu operation, allowing for a more user-friendly and truly interactive procedure.

Claims

1 Control apparatus for the remote control of data or equipment, comprising:

a screen;

input means;

sensing means for sensing data related to a position of the input means relative to the screen;

control means for determining the position of the input means relative to said screen from the data;

wherein:

the input means includes a source of electromagnetic radiation for directing onto the screen;

the sensing means includes detection means for detecting electromagnetic radiation directed onto, and scattered by the screen;

the detection means is configured to produce a detector output dependent on scattered electro-magnetic radiation detected;

and the control means is configured to analyse the detector output to determine the position of the source relative to the screen.

2 An electronic device as claimed in claim 1 wherein the source is configured to produce a conical beam of infrared radiation for directing onto the screen to form an elliptical area of incident radiation.

3 An electronic device as claimed in claim 1 wherein the source is configured to produce a laser beam for directing onto the screen.

4 An electronic device as claimed in claim 2 wherein the control means is configured to

analyse the detector output, to measure the length of either a major axis or a minor axis of the incident elliptical area, and to calculate the distance between the source and the screen from said measured length.

5 An electronic device as claimed in claim 2 or 4 wherein the control means is configured to analyse the detector output to measure angle related parameters of electro-magnetic radiation directed by the source onto the screen, and to determine the angle of the source relative to screen from the measured parameters.

6 An electronic device as claimed in claim 5 wherein the area related parameters include the length of either a major axis or a minor axis of the incident elliptical area.

7 An electronic device as claimed in claim 3 wherein the source is configured to split the laser beam into a plurality of components for directing onto the screen to form a plurality of corresponding incident points.

8 An electronic device as claimed in claim 7 wherein the control means is configured to analyse the detector output to measure the distances between the incident points.

9 An electronic device as claimed in claim 7 wherein the control means is configured to determine the distance of the source from the screen from at least one of the measured distances.

10 An electronic device as claimed in claim 8 or 9 wherein the control means is configured to determine the angle of the source relative to the screen from the measured distances.

11 An electronic device as claimed in any preceding claim wherein the detection means comprises a plurality of detectors arranged along at least one edge of the screen; each detector being configured to produce an analogue output dependent on the quantity of scattered light detected by it.

12 An electronic device as claimed in claim 10 wherein the detection means is

configured to produce detector output in the form of a serial signal, and the detection means further comprises a converter configured to convert the analogue outputs into the serial signal.

13 A method of determining a position of an input means relative to a screen comprising:

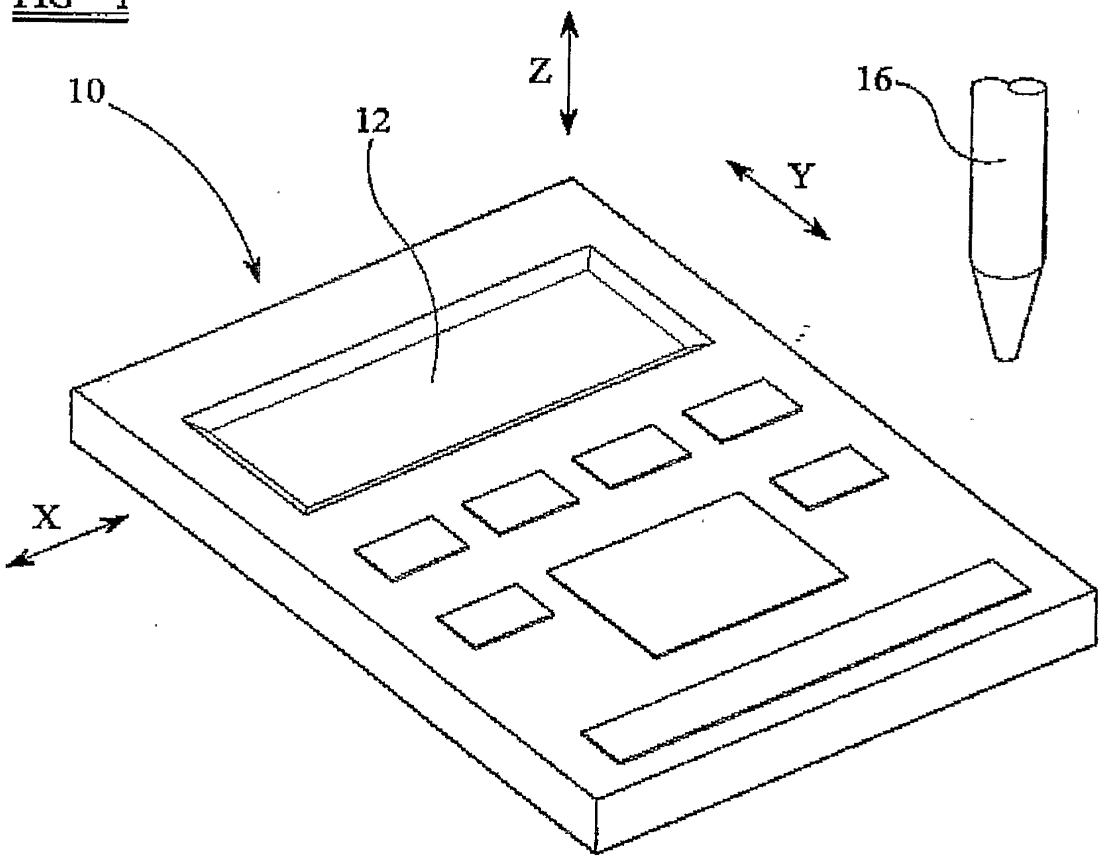
directing electromagnetic radiation onto the screen from the input device;

detecting electromagnetic radiation directed onto, and scattered by the screen;

producing a detector output dependent on scattered electro-magnetic radiation detected; and

analysing the detector output to determine the position of the input device relative to the screen.

FIG 1



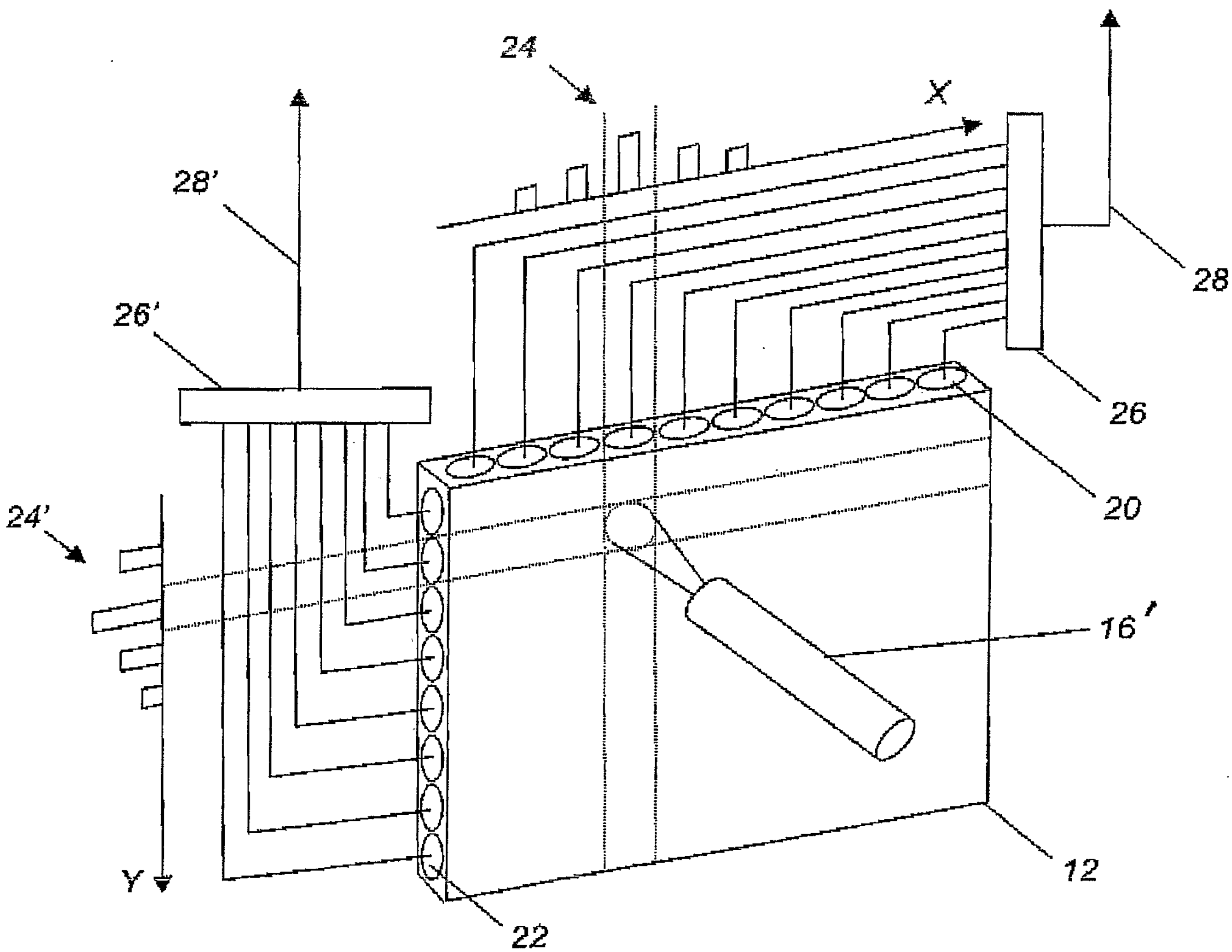


Fig 2

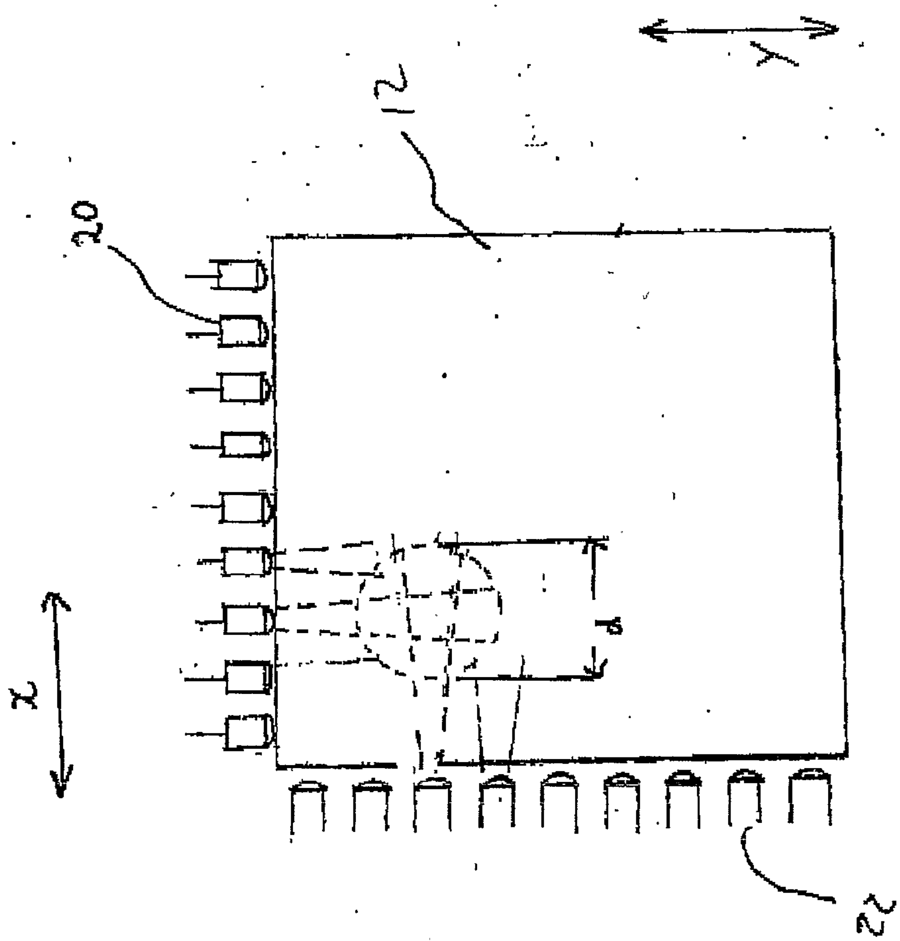


Fig 3

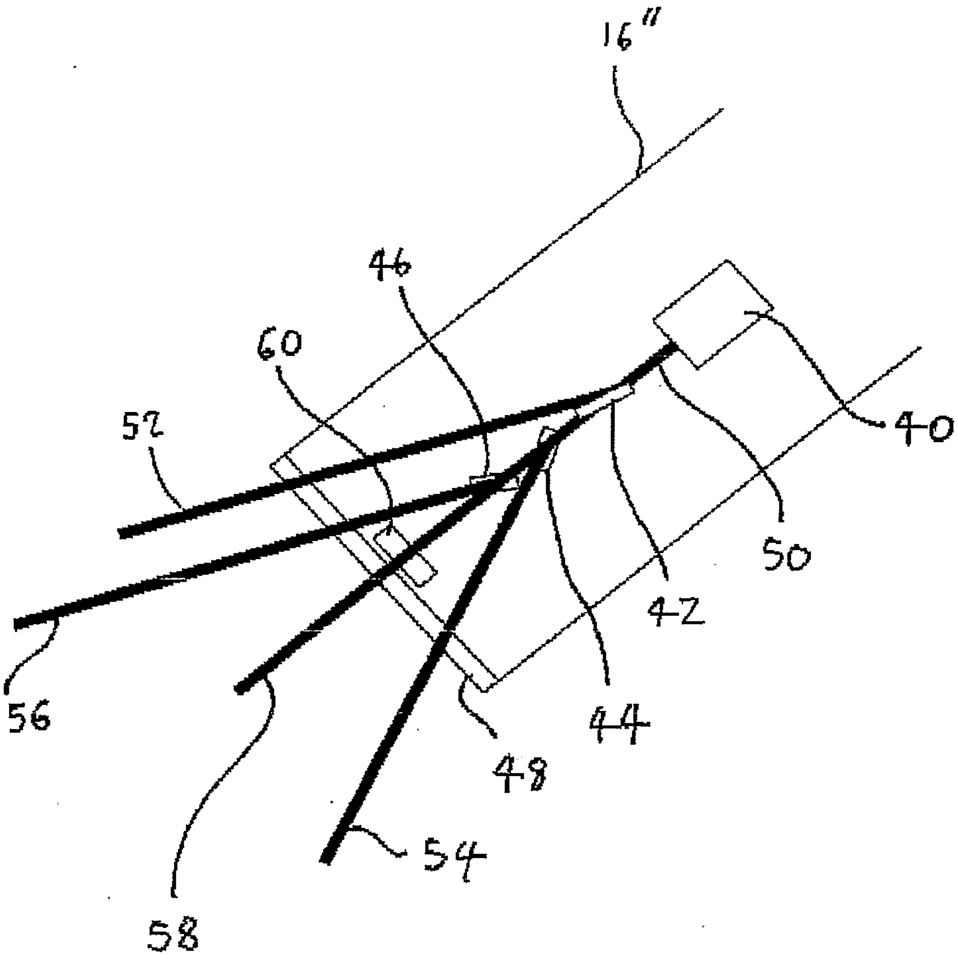


Fig 4

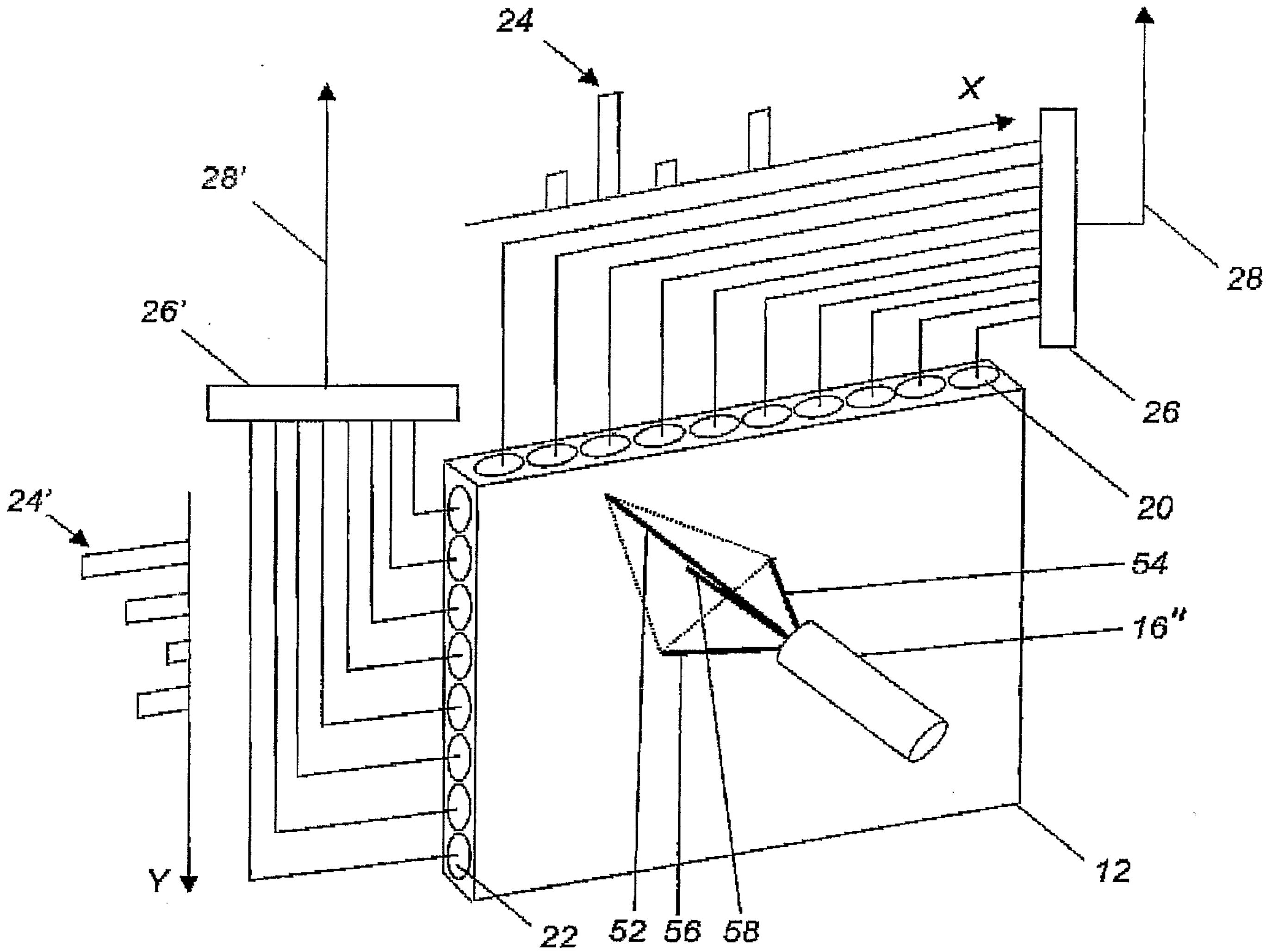


Fig 5

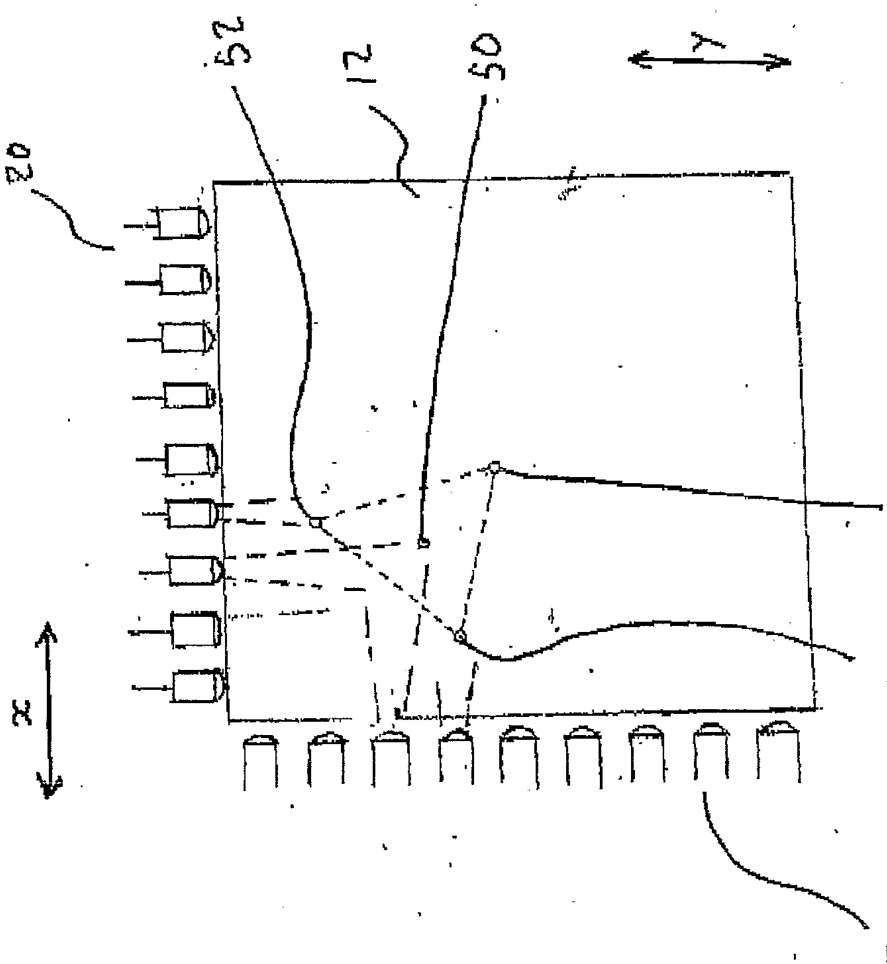


Fig 6